AGENG
MILANO '94

REPORT N. 94-G-062

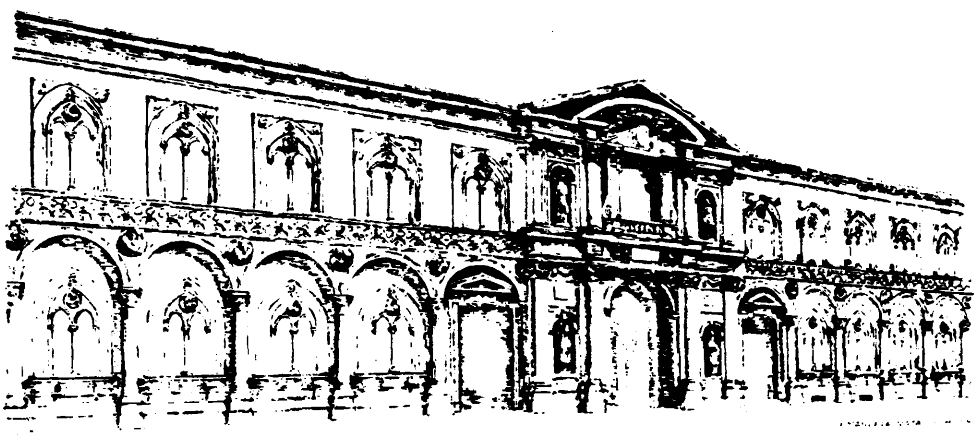
FACTORS INFLUENCING APPLE AND PEAR PHYSICAL PROPERTIES AND BRUISE SUSCEPTIBILITY

J. L. García, M. Ruiz-Altisent and P. Barreiro
Departamento de Ingeniería Rural, Universidad Politécnica,
Madrid, Spain

SUMMARY:

Fruit turgidity and firmness have shown to influence impact bruise susceptibility in apples and pears. Analysis of the impact response showed that stresses in the tissues are higher in turgid fruits, so they are more susceptible to bruising. A physical parameter, deformation at skin puncture, was able to detect fruit turgidity changes and showed to be related to bruise susceptibility.

KEYWORDS: Bruising, Impact, Fruit



1. Introduction

Bruise damage is a major cause of quality loss for fresh fruit market apples; most bruising occurs as a result of impacts. Several researchers have shown that bruising is linearly related to impact energy (Chen and Sun, 1981; Pang et al., 1992), but the amount of bruising which occurs at a constant energy impact is variable.
Several factors have been found influencing bruise susceptibility, but frequently researchers have obtained conflicting results. Klein (1987) and Johnson and Dover (1990) showed that bruising increased from early to late harvest time. However, Diener et al. (1979) reported that bruising decreased as apple matured.
With respect to storage, Klein (1987) concluded that bruise volume decreased during storage time. On the other hand, Brusewitz and Bartsch (1989) reported that change in bruise volume per unit change in approach (input) energy increased with storage time.
Fruit turgidity and firmness seem to affect bruise susceptibility. Horsfield et al. (1972) noted that desiccating the fruit to reduce turgor decreased bruise damage. Siyami et al. (1988) and Timm et al. (1989) found significant negative correlations between Magness-Taylor firmness and bruise diameter.
Saltveit (1984) reported that bruise susceptibility increased with increasing fruit temperature; however, Schoorl and Holt (1978) reported the opposite effect.

2. Materials and methods

"Blanquilla" pears and "Golden Supreme" and "Golden Delicious" apples, harvested in commercial orchards of Lérida (Spain), were used to determine the effect of harvest date, storage, irrigation and humidity conditions on bruising, according to the following scheme.

For "Blanquilla" pears, crossed factors were:
- Three harvest dates (9/VIII, 16/VIII, 23/VIII/93)
- Fruits tested the day after harvest, and fruits tested after 2 months in cold storage (1 °C, 85% RH).

480 (3x2x80) pears were tested.

For "Golden Supreme" and "Golden Delicious" apples, crossed factors were:
- Irrigation (three treatments). Trees without irrigation (during two weeks before first harvest), trees normally irrigated (2-l/h drips) and trees over-irrigated (4-l/h drips, during two weeks before first harvest).
- Relative humidity conditions (two treatments). Apples tested after 16 hours in 100% RH conditions (inside plastic bags), and apples tested after 16 hours in ±40% RH conditions (with air ventilation).
- Three harvest dates (29/VII, 5/VIII, 12/VIII/93 -"Golden Supreme"- and 6/IX, 13/IX, 20/IX/93 -"Golden Delicious"-)
- Fruits tested the day after harvest, and fruits tested after 3 months in cold storage (1 °C, 85% RH).

1080 (3x2x6x2x15) apples were tested.

These experiments are part of the CAMAR Project of the European Communities "Fruit Quality Engineering", where a total number of 1260 "Golden Delicious", 540 "Golden

Supreme", 240 "Granny Smith", 720 "Blanquilla", 720 "Conference" and 180 "Jules Guyot" fruits, grown in Lérida (Spain), were tested over two years (1992 and 93).

Tests applied to the fruits were the following:
- **Penetration test**. Performed using an Instron Universal Testing Machine with a standard Magness-Taylor 8-mm-diameter plunger at 20 mm/min, with the skin removed. Maximum force (Magness-Taylor firmness) was measured.
- **Skin puncture**. Performed using the same Instron Machine with a 0.5-mm-diameter puncture rod at 20 mm/min. Maximum force and deformation were measured.
- **Impact test**. Impact tester used has been described previously (García et al., 1988). The test was conducted using an instrumented free falling mass (50.8 g) with 20-mm-diameter spherical head, dropped onto the fruit from a height of 8 cm. Impact parameters (maximum force, deformation) were recorded and bruises produced were measured.
- **Bruise size measurement**. Bruises were allowed to develop for over 2 h. Then, maximum width and depth of the bruise were measured with a stereoscopic microscope, cutting through the center of the bruised region. The volume of bruised tissue was calculated using the equation of Chen and Sun (1981).

3. Results and discussion

3.1. Effect of irrigation

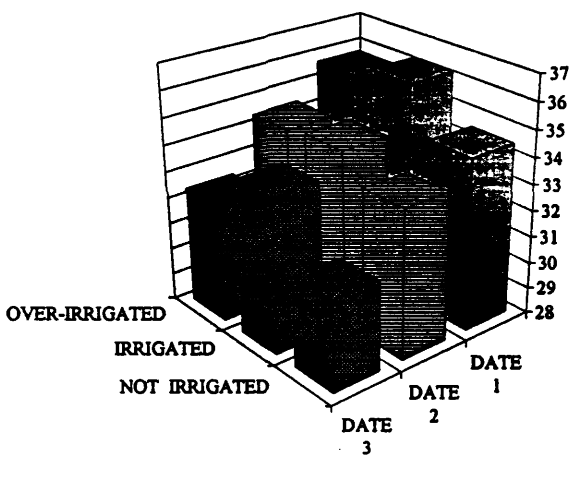
Irrigation schedules in the last weeks before harvest showed to influence fruit firmness. Normally watered trees produced firmer fruit than not irrigated or over-irrigated trees; the decrease in firmness was more important in trees without irrigation, presumably since ripeness rate of fruits was affected (Fig. 1). No changes were detected in skin physical properties or bruise susceptibility with respect to irrigation schedules.

3.2. Effect of air relative humidity

Fruits under different air relative humidity conditions, during the hours preceding testing, showed differences in their physical properties and bruise susceptibility (Table 1).
The maintenance of "Golden Supreme" and "Golden Delicious" apples in dry conditions ($\pm$40% RH and 20° C, with ventilation) led after 16 hours to weight loss smaller than 1%, presumably in the external layers of the fruit, while fruits at the same temperature in wet air conditions (100% RH) did not suffer any weight loss.
No changes in visible appearance were detected. However, fruit physical properties were affected. Deformation at skin puncture (DSP) was the more related parameter to weight loss (Table 1). This loss is mainly water loss, so deformation at skin puncture showed to be a parameter closely related with fruit turgidity.
Other experiments confirmed these results. Tests with "Golden Delicious" apples ripening several days at room temperature showed also good relationships between weight loss and deformation at skin puncture (Fig. 2). The values of deformation at skin puncture were always lower than 0.7 mm at harvest (turgid fruits) and higher than 0.7 after storage (less turgid fruits) in "Golden Supreme" and "Golden Delicious" apples and also in "Blanquilla" and "Conference" pears, with more than 3200 fruits tested (x-axis in Figs. 3 and 4). We can conclude that there is a relationship between deformation at skin puncture and fruit turgidity.

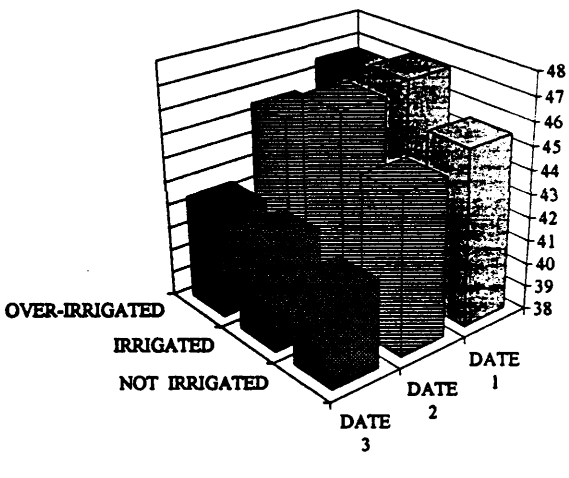
Magness-Taylor firmness was not affected by air relative humidity conditions, except in one case (Table 1, firmness values). This shows that air humidity conditions probably have no significant effect on the stregth of the tissues.
Bruise susceptibility showed significant differences when subjected to the different air humidity treatments (Table 1, bruise volume values); apples in high air humidity conditions showed to be more susceptible.
A relationship was found between one physical parameter (deformation at skin puncture, DSP) and bruise susceptibility (Figs. 3 and 4). Fruits with low values of DSP (turgid fruits) showed higher values of bruise volume in "Golden Supreme" and "Golden Delicious" apples and in "Blanquilla" pears. This relationship can be explained according to Hertz´s contact theory. Turgid fruits showed to have a different impact response -with respect to less turgid fruits-. Figs. 5 and 6 show that impact forces were higher and impact deformations were lower in turgid fruits, for the same energy levels. Stresses in the tissue were higher, while tissue resistance did not change strongly between both groups of fruits -tissue resistance is related to Magness-Taylor firmness (Horsfield et al., 1972)-. The stress increase would be, indeed, the reason for the increase of bruising.
The differences in turgidity can also explain why fruits at harvest were more susceptible to bruising than fruits after storage (Table 1, Figs. 3 and 4), as observed previously by other researchers.

Firmness, N



"Golden Delicious" apples

Firmness, N



"Golden Supreme" apples

Fig. 1. Firmness values for different irrigation schedules ("Over-irrigated": watered with 4-l/h drips, during two weeks before first harvest; "Irrigated": watered with 2-l/h drips; "Not irrigated": without watering during two weeks before first harvest). Harvest dates with differences of one week. Each column is the mean of 30 observations

n = 4x270	Weight loss, %	Firmness, N	Deformation at skin puncture, mm	Bruise volume, mm^3
Golden Supreme (at harvest)	Low RH 0.6 A	45.0 NS	0.6 A	134 A
	High RH 0.0 B	44.5 NS	0.5 B	140 B
Golden Supreme (after storage)	Low RH 0.3 a	40.9 ns	0.9 a	109 ns
	High RH 0.0 b	41.4 ns	0.8 b	113 ns
Golden Delicious (at harvest)	Low RH 0.4 A	34.3 NS	0.6 A	124 A
	High RH 0.0 B	33.8 NS	0.5 B	132 B
Golden Delicious (after storage)	Low RH 0.4 a	23.7 a	1.0 a	114 a
	High RH 0.0 b	24.6 b	0.9 b	121 b

Table 1. Effects of air relative humidity around the fruit (High RH: 100%; Low RH: ±40%) in the last 16 hours before testing on physical properties and bruise susceptibility of "Golden Supreme" and "Golden Delicious" apples, at harvest and after storage. Level of significance $\alpha=0.05$

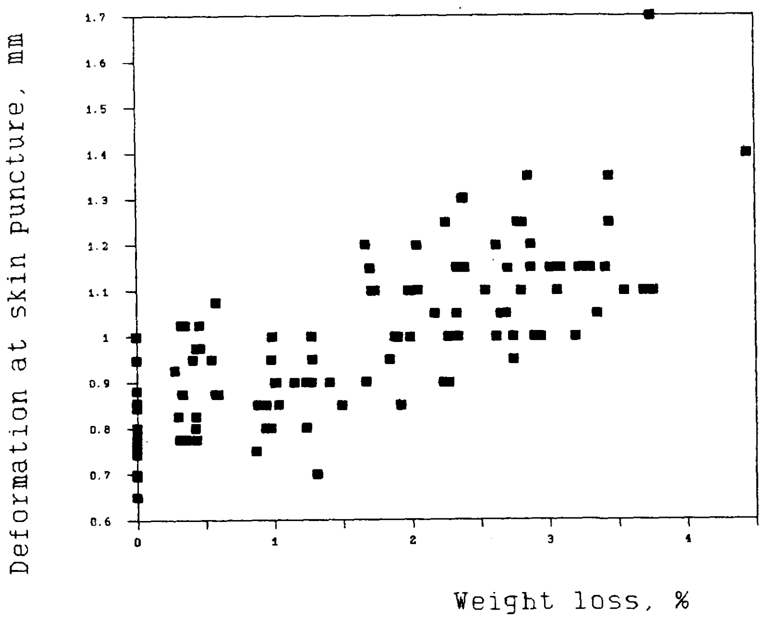
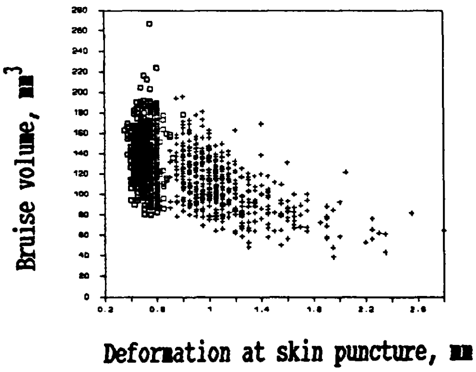


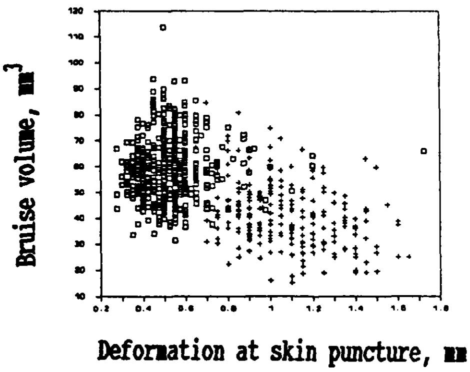
Fig. 2. Relationship between deformation at skin puncture, pysical parameter re'ated to fruit turgidity, and weight loss in "Golden Delicious" apples, ripening in room conditions (20°C, ±40% RH). n = 120, r = 0.77

"Golden Delicious" apples



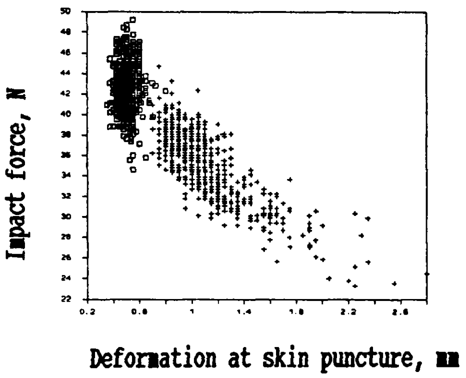
□: At harvest +: After storage

"Blanquilla" pears

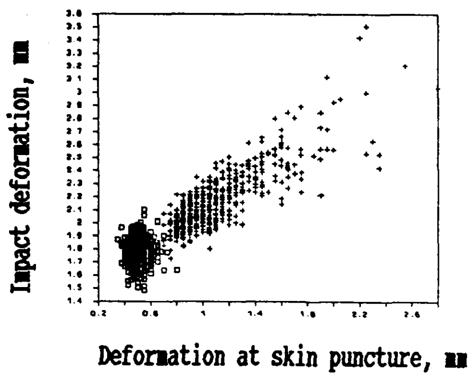


□: At harvest +: After storage

<u>Figs. 3 and 4.</u> Relationship between deformation at skin puncture, physical parameter related to fruit turgidity, and bruise susceptibility in "Golden Delicious" apples (n = 1260, r = -0.59) and in "Blanquilla" pears (n = 720, r = -0.56), at harvest and after storage. All impacts with the same energy levels



□: At harvest +: After storage



□: At harvest +: After storage

<u>Figs. 5 and 6.</u> Relationship between deformation at skin puncture and impact maximum force (n = 1199, r = -0.87), and impact maximum deformation (n = 1199, r = 0.90), in "Golden Delicious" apples, at harvest and after storage. All impacts with the same energy levels

3.3. Effect of harvest date and firmness

With respect to harvest date, many researchers have reported that early picked fruits are less susceptible to bruising (Klein, 1987; Johnson and Dover, 1990). Our results agreed with this statement. However, this change in bruise susceptibility can not be explained by fruit turgidity, since all the fruits are turgid at harvest for normal growing conditions.

Our results showed that Magness-Taylor firmness also influences bruise susceptibility. The influence of fruit turgidity was higher than that of firmness. When testing fruit with similar turgidity (for instance, at harvest), firmer fruit showed to be less susceptible to bruising (Table 2).

The relationship between firmness and bruise susceptibility was closer in pears than in apples, since ripening rate was faster in pears and the range of firmness values wider. Both parameters (firmness and turgidity) had no relationship between one another and influenced bruising independently. Two linear regression models, for "Golden Delicious" apples and for "Blanquilla" pears, were established considering these two parameters, for bruises produced with the same impact energy.

For "Golden Delicious" apples (n = 1260, individual fruits; bruise volume range, 50-200 mm^3; firmness range, 10-40 N; DSP range, 0.3-2.4 mm):

$$BV = 193.2 - 0.82\ F - 59.7\ DSP \qquad r^2 = 0.37$$

For "Blanquilla" pears (n = 720, individual fruits; bruise volume range, 20-90 mm^3; firmness range, 40-90 N; DSP range, 0.3-1.6 mm):

$$BV = 107.6 - 0.51\ F - 32.6\ DSP \qquad r^2 = 0.39$$

BV : Bruise volume, mm^3
F : Magness-Taylor firmness, N
DSP: Deformation at skin puncture, mm

These models have been calculated to show that the parameter DSP explains the 34% of the total variation in "Golden Delicious" apples and the 31% in "Blanquilla" pears. Adding the Magness-Taylor firmness, models can explain the 37% and 39% of the total variation, respectively.

Golden Supreme	Golden Delicious	Granny Smith	Blanquilla	Conference	Jules Guyot
n= 270	n= 710	n= 240	n= 480	n= 480	n= 180
r= -0.20	r= -0.26	r= -0.26	r= -0.41	r= -0.33	r= -0.45

Table 2. Correlation coefficients between bruise volume, mm^3, and firmness, N, in several apple and pear varieties; fruits tested the day after harvest. All correlations are significant at the level of 1%

According to the models, bruise susceptibility is affected by fruit turgidity and firmness changes during ripening; bruise damage would decrease due to fruit turgidity decrease, or would increase due to firmness decrease, depending on which is the main factor in the ripening process. This can be the cause of the conflicting results obtained by several researchers.
Similar considerations can be made with respect to temperature. A temperature increase can affect fruit properties decreasing fruit turgidity (due to water loss) or decreasing fruit firmness (due to changes in the ripening rate), depending on the experimental conditions. The models can explain the different results obtained by previous works relating bruise susceptibility to temperature changes.

4. Conclusions

- Irrigation schedules showed to influence fruit firmness. Normally watered trees produced firmer fruit than not irrigated and over-irrigated trees.
- Humidity conditions around the fruit in the last 16 hours before testing affected fruit physical properties and bruise susceptibility. Fruits with high turgidity were more susceptible to bruising.
- Deformation at skin puncture showed to be the physical parameter more related to fruit turgidity. This parameter was also related to bruise susceptibility.
- Fruit at harvest was more susceptible to bruising than fruit after storage, and that is explained by fruit turgidity decrease.
- Early picked fruits were less susceptible to bruise than later picked fruits, and that is explained by fruit firmness decrease.
- It is shown that turgidity and firmness influence bruise susceptibility independently. Their effects combine each other during fruit ripening.

Further modeling is being performed, for these and for other fruit species, including further parameters with the aim of explainig bruising.

References

1) Brusewitz, G. H. and J. A. Bartsch. *Impact parameters related to post harvest bruising of apples.* Transactions of the ASAE 1989, 32(3):953-957

2) Chen, P. and Z. Sun. *Impact parameters related to bruise injury in apples.* ASAE Paper No. 81-3041, 1981

3) Diener, R. G., K. C. Elliot, P. E. Nesselroad, M. Ingle, R. E. Adams and S. H. Blizzard. *Bruise energy of peaches and apples.* Transactions of the ASAE 1979, 22(2):287-290

4) García, C., M. Ruiz-Altisent and P. Chen. *Impact parameters related to bruising in selected fruits.* ASAE Paper No. 88-6027, 1988

5) Horsfield, B. C., R. B. Fridley and L. L. Claypool. *Application of theory of elasticity to the design of fruit harvesting and handling equipment for minimum bruising.* Transactions of the ASAE 1972, 15(4):746-750

6) Johnson, D. S. and C. J. Dover. *Factors influencing the bruise susceptibility of Bramley's Seedling apples.* Proceedings of the European Workshop on Impact Damage of Fruits and Vegetables. Zaragoza (Spain) 1990, 87-93

7) Klein, J. D. *Relationship of harvest date, storage conditions, and fruit characteristics to bruise susceptibility of apple.* Journal of American Society of Horticultural Science 1987, 112(1):113-118

8) Pang, W., C. J. Studman and G. T. Ward. *Bruising damage in apple-to-apple impact.* Journal of Agricultural Engineering Research 1992, 52:229-240

9) Saltveit, M. E. *Effects of temperature on firmness and bruising of Starkrimson Delicious and Golden Delicious apples.* Horticultural Science 1984, 19(4):550-551

10) Schoorl, D. and J. E. Holt. *The effects of storage time and temperature on the bruising of Jonathan, Delicious and Granny Smith apples.* Journal of Texture Studies 1978, 8:409-416

11) Siyami, S., G. K. Brown, G. J. Burgess, J. B. Gerrish, B. R. Tennes, C. L. Burton and R. H. Zapp. *Apple impact bruise prediction models.* Transactions of the ASAE 1988, 31(4):1038-1046

12) Timm, E. J., N. L. Schulte-Pason, G. K. Brown and C. L. Burton. *Apple and impact surface effects on bruise size.* ASAE Paper No. 89-6048, 1989